PATENT SPECIFICATION

DRAWINGS ATTACHED

1,080,015

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Date of filing Complete Specification (under Section 3 (3) of the Patents Act 1949): Jan. 21, 1965.

Application Date: Nov. 13, 1963. *No. 44882/63.*

Application Date: Jan. 14, 1964. *No. 1596/64.*

Complete Specification Published: Aug. 23, 1967.

dex at acceptance:—F1 T(B1N, B2B2)

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COMPLETE SPECIFICATION

Steam Turbines

We, THE ENGLISH ELECTRIC COMPANY LIMITED, of English Electric House, Strand, London, W.C.2., a British Company, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to axial flow steam turbines.

According to the invention, in an axial flow steam turbine including a rotor carrying a plurality of rows of rotor blades, said rotor being arranged within a casing which carries a plurality of rows of stationary blades and the rows of stationary blades being arranged alternately with the rows of rotor blades the product of the number N of stationary blades in at least one row thereof and of the width a of said stationary blades, measured in a direction parallel to the axis of the rotor, divided by the radial length h of each rotor blade in the next row thereof downstream of said stationary blades, is at most 12, the ratio of the said width a and said radial length h being at most 0.15.

According to a preferred feature of the invention, the axial distance b between the trailing edge of the stationary blades in at least one row thereof and the leading edge of the rotor blades in the nest row thereof downstream of said stationary blades is equal to or greater than said width a of the stationary blades.

Preferred embodiments of the invention will now be described by way of example and with reference to Figs. 1 and 2 of the drawings accompanying the Provisional Specification of Application No. 44882/63, of which:—

Fig. 1 is a longitudinal sectional view of part of an axial flow steam turbine of known design including blades in the last two stages of the rotor at the low-pressure end of the turbine; and

Fig. 2 is a section on the line II—II of the corresponding Fig. 1;

and to the drawings accompanying the Provisional Specification of Application No. 1596/64, of which:—

Fig. 1 is a longitudinal sectional view, corresponding with the view shown in Fig. 1 of Application No. 44882/63 but showing part of an axial flow steam turbine according to the present invention; and

Fig. 2 is a section on the line II—II of the corresponding Fig. 1.

With reference firstly to Figs. 1 and 2 of Application No. 44882/63, there are shown parts of the rotor 11 in the low-pressure cylinder of a steam turbine which may also comprise high-pressure and intermediate pressure cylinders. The rotor 11 carries a penultimate row of rotor blades 12 and a last row of rotor blades 13.

The low-pressure cylinder has a stationary casing 14, which is co-axial with the rotor 11 and in which is mounted a last-stage row of stationary blades 15 defining steam nozzles between them. The stationary blades 15 carry an annular ring 16 at their inner ends and a steam seal (not shown) is provided between the annular ring 16 and the rotor 11.

A cross-section through the last-stage stationary blades and rotor blades is shown in Fig. 2.

With reference now to the drawings accompanying Application No. 1596/64 there are shown parts of the rotor 11 in the low-pressure cylinder of another steam turbine, again carrying a penultimate row of rotor blades 12 and a last row of rotor blades 13.

The low-pressure cylinder has a casing 34 which is again coaxial with the rotor 11 and in which is mounted a last-stage row of stationary blades 35, defining steam nozzles between them. The stationary blades 35 again carry an annular ring 16 at their inner ends.

In comparison with the blades shown in

Figs. 1 and 2 of Application No. 44882/63, it will be seen that the stationary blades 35 have a much shorter chord (indicated at *c*) than the blades 15, and that the axial distance (indicated at *b*) between the trailing edge of the stationary blades 35 and the leading edge of the next row of rotor blades 13 downstream of those stationary blades is therefore considerably greater.

It has been found that reduced erosion of the wet stages (i.e. those stages at the low-pressure end of the low-pressure unit in which condensation of the steam occurs, including the last stage of blades 13 and the penultimate stage 12) is achieved by ensuring that the total surface area of the stationary blades is kept to a minimum. This may be achieved not only by reducing the chord *c* of the stationary blades, but also by reducing the number *N* of these blades. While the total surface area of the stationary blades (projected in a plane perpendicular to the general direction of steam flow indicated by the arrow 'X') which is proportional to the product *Nc*, should therefore be kept to a minimum consistent with the retention of good aerodynamic control of the flow of steam, it is preferred to reduce the chord *c*, and consequently the width of the blades (indicated at *a*) measured in a direction parallel with the rotor axis, since this enables the axial distance *b* between the trailing edge of the stationary blades and the leading edge of the corresponding rotor blades to be increased without increasing the axial length of the rotor 11. This offers the advantage that large drops shed from the fixed blade 35 have as great a distance as possible in which to be broken up by the disrupting action of steam blown past them.

In a steam turbine designed for a speed of 3000 r.p.m. of the kind shown in Figs. 1 and 2 of Application No. 44882/63, in which the mean diameter *D* of the last row of rotor blades is 100 inches, the radial length *h* of these blades being 36 inches, a typical value of the width *a*, measured adjacent the tip of the stationary blades, is of the order of 6 inches, and a typical value of the axial distance *b*, measured adjacent the tip of the stationary blades, is of the order of 1.5 inches.

In one typical turbine in accordance with the present invention, i.e. as shown in the drawings of Application No. 1596/64 also designed for a speed of 3000 r.p.m. and having a mean diameter D of 100 inches and blade radial length *h* of 36 inches, the value of width *a* is 2.5 inches and that of the distance *b* is 5.25 inches. Moreover, in this particular case the number of stationary blades is also reduced compared with the example given above.

Ranges of typical values of *a* and *b* in accordance with the present invention, for different rotational speeds and blade heights, are shown in the following Table 1:—

TABLE 1

Rotor Speed (rpm)	Blade radial length *h* (inches)	Width *a* (inches)	Axial distance *b* (inches)
3,000	27	2 — 3	4 — 7.5
	36	2.5 — 3	5 — 10
	45	2.5 — 4	6 — 12.5
1,500	55	4 — 6	4 — 7.5
	65	5 — 6	4.5 — 9
	72	5 — 8	5 — 10
3,600	23	2 — 3	4 — 7.5
	30	2.5 — 3	5 — 10
	38	2.5 — 4	6 — 12.5
1,800	46	4 — 6	4 — 7.5
	54	5 — 6	4.5 — 9
	60	5 — 8	5 — 10

The number of stationary blades 35 in the last row of a turbine in accordance with the present invention is preferably 70 to 80, as compared with some 90 to 100 blades in corresponding turbines of this size of the kind shown in Figs. 1 and 2 of Application No. 44882/63.

Thus the wetted area of each stationary blade is considerably reduced, being substantially proportional to the chord *c* and therefore to the value of the width *a*.

From Table 1, ranges of values for the ratio $\frac{Na}{h}$, i.e. the product of the number of stationary blades 35 in a row and of their

width a, divided by the length of each corresponding rotor blade 13, may be calculated.

Ranges of values of this ratio $\frac{Na}{h}$ are set out in Column A of the following Table 2, for the twelve examples in Table 1, the number N being taken as 70 to 80 blades.

TABLE 2

Rotor Speed (rpm)	Blade radial length h (inches)	A
3,000	27 36 45	7.8 — 8.9 5.8 — 6.7 6.2 — 7.1
1,500	55 65 72	7.6 — 8.7 6.5 — 7.4 7.8 — 8.9
3,600	23 30 38	9.1 — 10.4 7.0 — 8.0 7.6 — 8.4
1,800	46 54 60	9.1 — 10.4 7.8 — 8.9 9.3 — 10.7

It can be seen from Table 2 that in an arrangement according to the present invention the ratio $\frac{Na}{h}$ is always less than 12, while in comparable known arrangements this ratio is at least 15. At the same time, in an arrangement according to this invention the greatest value of the ratio $\frac{a}{h}$ in the cases set out in the tables is 0.15.

It will be understood that the relative positions of the centre-lines of the discs 11 is unchanged as between the two Figures 1, this being determined by considerations of hub design, and thus the axial length of the turbine is uneffected by the invention.

It will also be noted that, whereas the chord c of the last row of stationary blades 15 was substantially constant from the root to the tip of the blades, the stationary blades 35 in accordance with the invention are preferably tapered so that their tip chord is less than the root chord.

The outer platforms of the stationary blades 35 may also have a lesser axial extent, and the groove in which they are housed in the casing 34 will be modified accordingly as compared with that in the casing 14.

It will be understood that the invention is not confined to the last two stages of the low-pressure part of the turbine, but may be applied in relation to any rows of blades in the turbine in which problems of erosion by wet steam may arise, the values of the distances a and b and of the chord c and number N of stationary blades, being modified from those shown in the table according to the radial length of the rotor blades concerned and the rotor speed.

WHAT WE CLAIM IS:—

1. An axial flow steam turbine including a rotor carrying a plurality of rows of rotor blades, said rotor being arranged, within a casing which carries a plurality of rows of stationary blades and the rows of stationary blades being arranged alternately with the rows of rotor blades, wherein the product of the number n of stationary blades in at least one row thereof and of the width a of said stationary blades, measured in a direction parallel to the axis of the rotor, divided by the radial length h of each rotor blade in the next row thereof downstream of said stationary blades, is at most 12, the ratio of the said width a and the said radial length h being at most 0.15.

2. A steam turbine according to Claim 1 wherein the axial distance b between the trailing edge of the stationary blades in at least one row thereof and the leading edge of the rotor blades in the next row thereof downstream of said stationary blades is equal to or greater than said width a of the stationary blades.

3. A steam turbine according to Claim 2, wherein said axial distance is at least four inches.

4. A steam turbine according to any preced-

ing claim, wherein each stationary blade in at least one row thereof is tapered so that said width thereof is greater at its radially-inner end than at its radially-outer end.

5. An axial flow steam turbine substantially as herein described with reference to Figs. 1 and 2 of the drawings accompanying the Provisional Specification of Application No. 1596/64 and to any one of the examples in the tables set forth herein.

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Chartered Patent Agent.

Leamington Spa: Printed for Her Majesty's Stationery Office, by the Courier Press.
—1967. Published by The Patent Office, 25 Southampton Buildings, London, W.C.2, from which copies may be obtained.

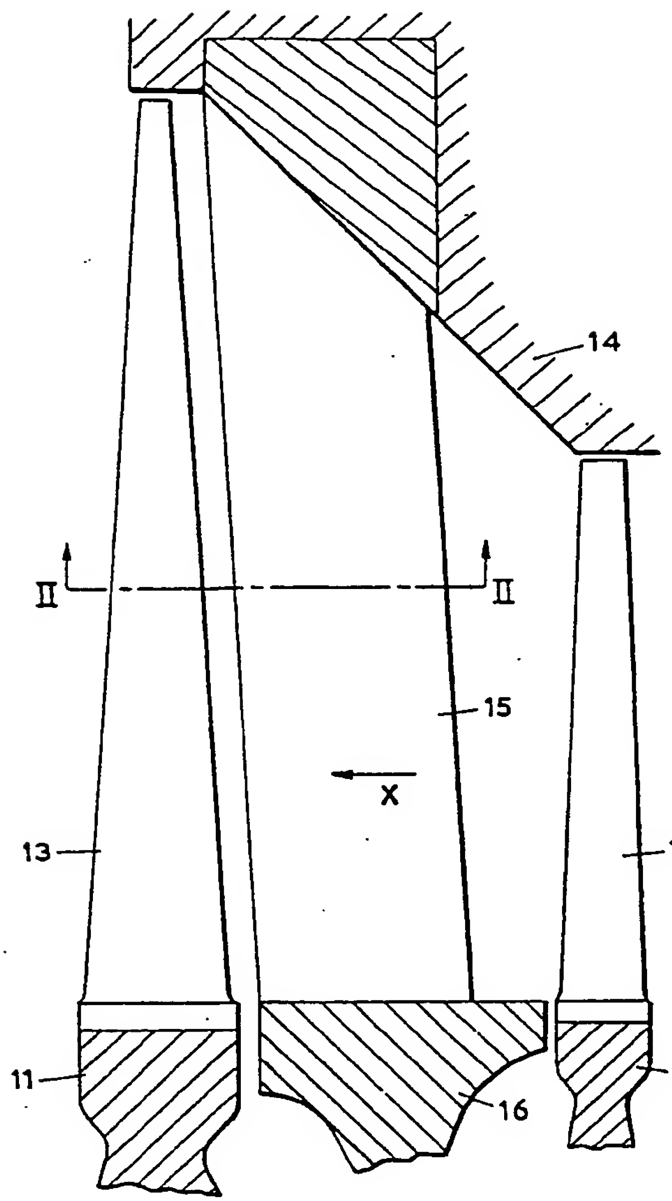

FIG.1

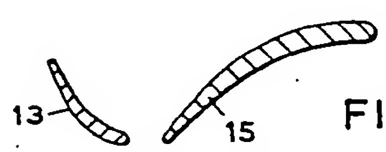

FIG.2

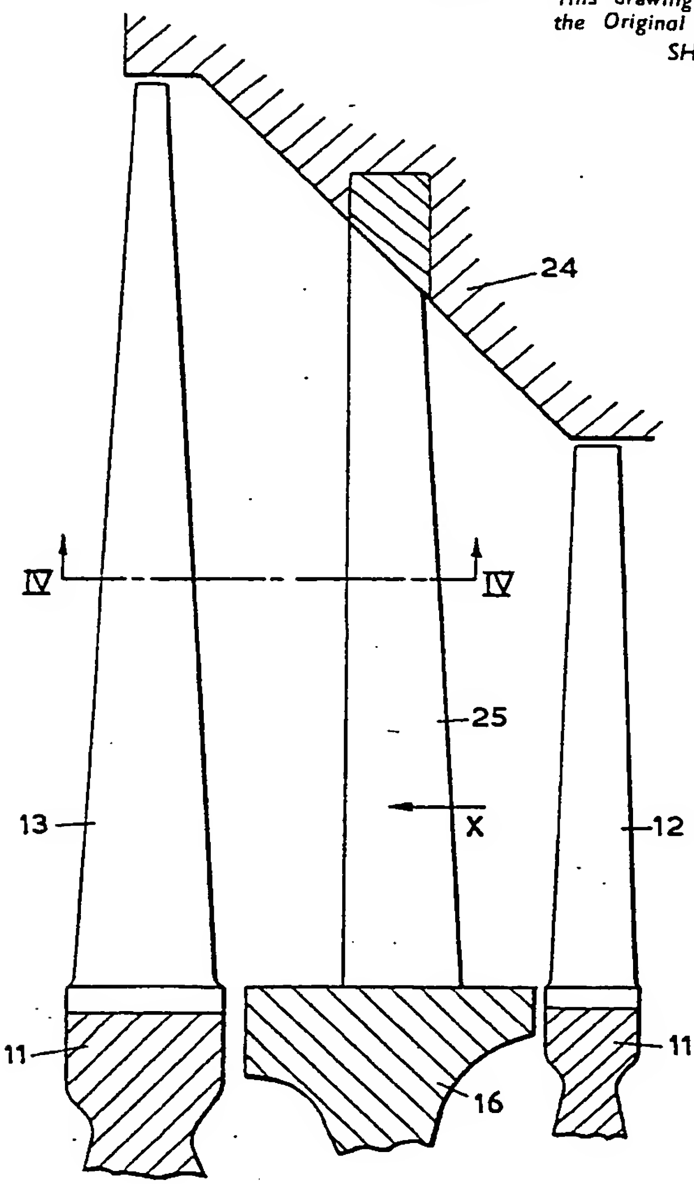

FIG.3

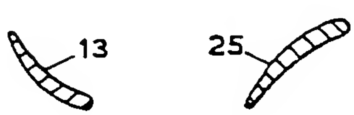

FIG.4

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1 SHEET
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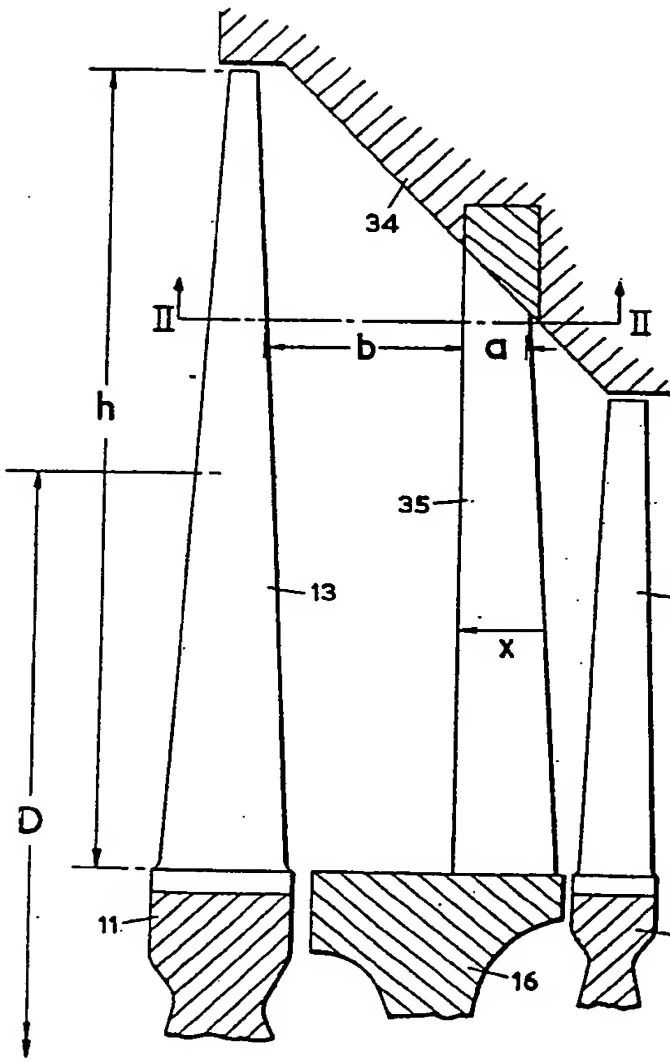

FIG. 1

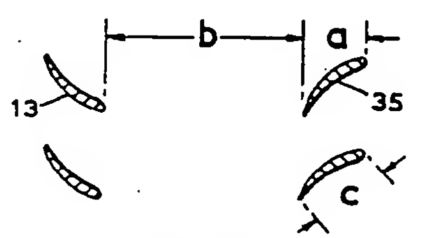

FIG. 2

1080015 PROVISIONAL SPECIFICATION No. 44882/63

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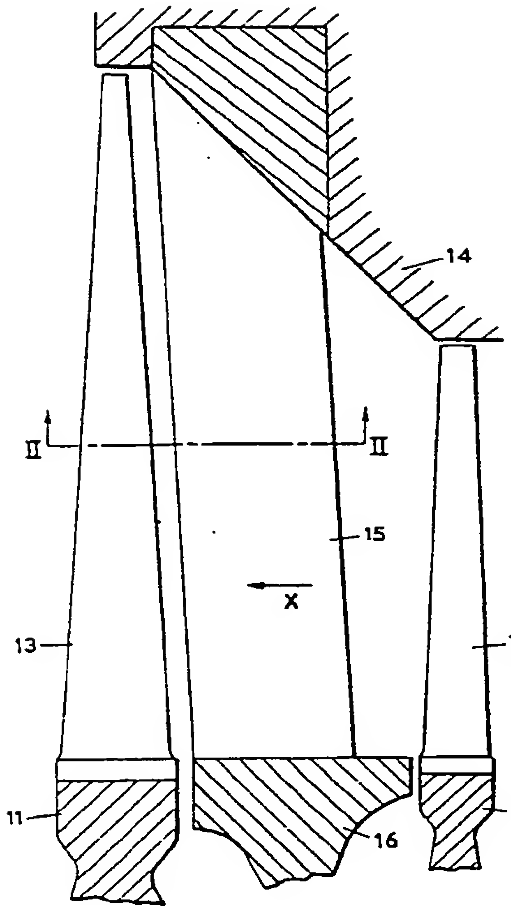

FIG.1

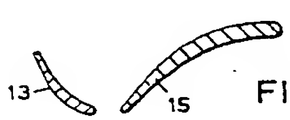

FIG.2